

TITLE OF THE INVENTION

**LOW FRICTION FIBERS, METHODS FOR THEIR PREPARATION AND ARTICLES
MADE THEREFROM**

FIELD OF THE INVENTION

The present invention is directed to fibers having a low coefficient of friction. More particularly, the invention provides fibers formed from a combination of at least two or more materials, such as a base polymer, such as polyethylene, and ultra-high molecular weight silicone, wherein one of the materials has a low coefficient of friction. Further, the invention is directed to a method and process for manufacturing the fibers and articles made therefrom.

Documents cited in the following text are incorporated herein by reference.

BACKGROUND OF THE INVENTION

Low-friction fibers, and products made therefrom, possess commercially desirable properties. Not only do such materials have beneficial wear characteristics for apparel, because of improved sliding properties when in contact with the skin, they also achieve higher performance through reduced frictional loss. Low-friction fibers traditionally are produced by a number of methods. Such methods include, for example, applying an external lubricant to a finished product, coating the material with a low-friction polymer layer, or adding inactive agents, such as spheroidal beads, during the formulation of the material. Other methods include forming multi-layer materials wherein one side has a low-friction surface.

In the patent literature, there are various methods of forming low-friction materials. For example, U.S. Patent No. 4,138,524 relates to a method of forming an article with an integral protective surface having a low coefficient of friction. Low friction is achieved by inserting chemically inactive spheroidal beads into a bonding material, wherein the density differential allows the beads to migrate to form a low-friction layer.

U.S. Patent No. 4,996,094 relates to a thermoplastic stretch wrap films with one cling layer and one slip layer. The cling portion is made of low density polymers and the slip portion is made of coextruded high density polyethylene resin.

U.S. Patent No. 4,996,094 relates to a stretch wrap film having one surface with cling properties and the other with non-cling properties, one noncling property being a slip property exhibited when the noncling surface is in contact with a like surface of itself with relative motion therebetween having the improvement which is comprised of positioning at least one region between the cling and noncling surfaces of the film, said region being of a material selected to provide barrier properties sufficient to maintain the cling and noncling properties of the cling and noncling surfaces. A high number average molecular weight cling additive is used to reduce additive migration and transfer.

U.S. Patent No. 5,750,620 relates to a polymeric composition including a blend of at least two different polymers selected from the group consisting of polystyrene, polycarbonate, polyetherimide, polyolefin, polysulphone, polyethersulphone, polyacetal, nylon, polyester, polyphenylene sulphide, polyphenylene oxide and polyetheretherketone and at least one elastomer having a tensile modulus less than about 50,000 p.s.i. Alternatively or additionally, the elastomer may be functionalized to graft with at least one of the polymers. The present invention also provides a method of making a tribological wear system by melt-mixing the polymeric composition to improve the wear resistance of a polymeric composite whose surface bears against another surface, thereby causing friction and wear of the polymeric composite.

U.S. Patent No. 6,093,482 relates to a carbon--carbon composite for friction products comprises an outer friction part and a load bearing structure part supporting the friction part. The friction part contains a mixture of carbon fibers, pitch powder and graphite powder, whereas the structure part is comprised of a pack of alternating layers of the mixture and layers of one member selected from the group consisting of carbon fabrics, carbon-based prepregs and carbon-based, segmented prepregs. The carbon--carbon composite is formed by way of alternately piling up layers of a mixture of carbon fibers, pitch powder and graphite powder and layers of one member selected from the group consisting of carbon fabrics, carbon-based prepregs and carbon-based, segmented prepregs one above the other to provide a preform, heating and pressing the preform within a mold to obtain a green body, carbonizing the green body to prepare a carbonized body, impregnating the carbonized body with pitch powder and recarbonizing the impregnated body, and subjecting the impregnated and recarbonized body to chemical vapor infiltration with hydrocarbon gas.

U.S. Patent 4,371,445 relates to a tribological system with plastic/plastic pairings,

especially sliding bearings, in which plastics--optionally supported by lubricants--carry out motions in sliding friction relative to one another and at least one of the main sliding partners and/or auxiliary partner is a plastic, containing polar, cyclic compounds, in which the cyclic part of the molecule on at least one side is coupled directly to an atom of Group V (especially nitrogen) or of Group VI (especially oxygen and/or sulfur) of the Periodic System of the elements, or in which the rings contain the atoms mentioned. Excellent sliding conditions are obtained when the polar synthetic materials, containing the cyclic compound(s), either are monovalent, cyclic chain polymers or chain polymers in the form of polyheterocycles ("semi-ladder polymers") or chain polymers in the form of monovalent polyheterocycles or fully cyclic chain polymers ("ladder polymers") or homopolymers or copolymers or polymer mixtures within the above groups or of these groups or with other molecules or polymers and either both main polymers are polar and contain different cyclic compounds, while the auxiliary sliding partner however is nonpolar, or that both main sliding partners are nonpolar, while the auxiliary sliding partner however is polar and contains cyclic compounds.

U.S. Patent No. 4,626,365 relates to a composition for sliding parts, comprising 0.1 to 50 vol % in total of at least one selected from the group (A) consisting of FEP, PFA, ETFE, PVDF, PCTFE and EPE; 0.1 to 35 vol % of compound metal oxide; and the balance PTFE, the total content of components other than PTFE ranging between 0.2 and 70 vol %. Such composition may further contain at least one of metal oxide, metallic lubricant, metal sulfide, metal fluoride, carbonic solid lubricant, fibrous material, ceramics.

U.S. Patent No. 4,812,367 relates to a material for a low-maintenance sliding surface bearing comprises a metallic backing and on said backing a bearing layer comprising PVDF and an additive for improving the friction and sliding properties. To meet more stringent requirements regarding hygiene, the bearing layer is free of lead and contains 0.5 to 3% by weight of a non-toxic metal oxide powder and 10 to 40% by weight of glass microspheres.

U.S. Patent No. 4,847,135 relates to a composite material for sliding surface bearings, a rough metallic surface is provided with a polymeric matrix, which forms a friction contact or sliding layer over the rough base surface. To increase the wear resistance, the matrix contains zinc sulfide and/or barium sulfate in a particle size from 0.1 to 1.0 μm and an average particle size of 0.3 μm .

U.S. Patent No. 5,527,594 relates to optical tape comprising a substrate having a

center line average roughness on one side of 0.005 to 0.5 μm and a tensile strength ($F_{0.5}$) in the longitudinal direction of not less than 8 kg/mm², and an optical recording layer formed on the other side of said substrate.

U.S. Patent No. 5,171,622 relates to a lacquer coating is applied to a laminated metal composite forming a sliding element such as a plane bearing and has particles of solid lubricants incorporated therein to form islets of greater thicknesses than the surrounding film and which serve as lubricant-trapping surface formations. The particles may be of polytetrafluoroethylene, fluorinated graphite or molybdenum disulfide and the lacquer is preferably an epoxy resin-based lacquer.

U.S. Patent No. 5,763,011 relates to a urethane-resin based coating for reducing friction includes a urethane paint and a first powder. The coating is to be applied to a shaped article which is to be subjected to a heat treatment at a certain temperature after the application of the coating to the shaped article. The first powder has a melting point lower than the certain temperature and a solubility parameter which is smaller than or larger than that of the urethane paint by at least 0.5. The coating optionally further includes a second powder which has a melting point higher than the certain temperature. The coating provides the shaped article with low friction, irrespective of the coating film's thickness

U.S. Patent No. 5,866,647 relates to a polymeric based composite bearing is injected molded of a thermoplastic material reinforced with a high strength fiber and reinforcing beads. Typically, the high strength fiber is selected from the group consisting of aromatic polyamide fiber, high strength/high purity glass fiber, carbon fiber, boron fiber, and metallic fibers. The reinforcing spheres are selected from the group consisting of glass beads, boron nitride beads, silicon carbide beads and silicon nitride beads. The thermoplastic matrix material may consist of polyamide, polyacetal, polyphenylene sulfide, polyester and polyimide. Preferably, the composite bearing comprises between about 5 to about 35 percent weight of the high strength fiber, between about 5 to about 15 percent weight percent of the reinforcing spheres, and between about 50 to about 90 weight percent of the thermoplastic matrix material. The bearing may be injection molded by blending the composite material, heating the composite material to a temperature above its melting temperature, injecting the composite material into a mold cavity, and demolding the bearing after the temperature of the bearing drops substantially below the melting temperature.

U.S. Patent No. 3,781,205 relates to a composite bearing comprising a backing member to which there is secured a dimensionally stable bearing surface layer comprising a solid lubricant selected from the group consisting of the sulfides, selenides, and tellurides of molybdenum, tungsten, and titanium, lead diiodine, boron nitride, carbon, graphite, and polytetrafluoroethylene and fibers of a material characterized by a heat distortion temperature exceeding that of polytetrafluoroethylene and selected from the class consisting of aromatic polyamides, carbon, graphite, aromatic polysulfones, aromatic polyimides and aromatic polyester-imides.

U.S. Patent No. 4,104,176 relates to a porous lubricant-impregnated bearing comprising a matrix of closely packed, discrete particles, such as glass microspheres, bonded together with a bonding material that is different from the particles, such as a cured organic bonding material, and that only partially fills the interstices between the particles; and a migratable lubricant dispersed in the unfilled interstices.

U.S. Patent No. 5,080,969 relates to a composite friction material for brakes comprising a main friction material containing thermosetting resin as a binder, and a layer of high friction material with a higher friction coefficient than said main friction material for exhibiting a high braking power on initial application, which high friction layer is provided on the surface of said main friction material and contains a phenol resin of not more than 5 wt. %.

U.S. Patent No. 4,201,777 relates to a unitary carbonaceous body consists of turbostratic carbon formed with a superficial graphitized portion in situ, preferably by passing a high-amperage electric current through this portion.

U.S. Patent No. 3,980,570 relates to a sliding member having anti-frictional and anti-static properties for a tape or film cassette of an audio- or video-tape recorder or a movie projector, comprising a thermoplastic resin containing 5 to 90% by weight of carbon fiber, said member having less than $10^{0.8}$ ohms of surface resistance and also having a coefficient of dynamic friction of less than 0.2.

U.S. Patent No. 5,082,512 relates to seizure resistance of boronized sliding material improved by surface microstructure, i.e., co-existence of the Fe_2B phase and Fe_3B phase.

U.S. Patent No. 5,093,388 relates to a high friction brake shoe formulation having a high static friction coefficient in shear of about 1.5 and low adhesion to materials having microscopic pores therein in contact with said brake shoe formulation which comprises a mixture

of about 75 phr of neoprene W rubber and about 25 phr of neoprene WHV rubber; a first curing system comprising about 1 phr of a fatty acid, about 5 phr of ZnO, and about 1-3 phr of MgO; and a second curing system comprising about 1.25 phr of sulfur and about 0.6 phr of a sulfur accelerator; together with about 50 phr of a reinforcing agent of N555 or N650 carbon black.

U.S. Patent 5,508,109 relates to a fiber blend for use in friction materials. The fiber contains a blend of a highly fibrillated fiber, such as a fibrillated polyacrylonitrile fiber and a fiber with a high carbon content, such as an oxidized carbon fiber precursor.

U.S. Patent 5,811,042 relates to a composite friction or gasketing material is disclosed having a combination of thermoset or thermo-plastic matrix resin, fiber reinforcing material, and aramid particles. The composite material exhibits improved wear resistance when compared with materials having no aramid particles.

U.S. Patent No. 5,889,080 relates to a method for making a dry blend for use in the preparation of a friction material, a dry blend per se and dry friction materials is disclosed wherein the components thereof include a) fibrillated, organic, synthetic polymer, b) organic, synthetic polymer staple and c) organic, synthetic soluble polymer particles.

It would be desirable to combine two or more components, wherein one of the components is a polymeric component and the other is a low friction component, to form a fiber imparted with a low coefficient of friction characteristic of a non-temporary nature.

OBJECTS AND SUMMARY OF THE INVENTION

An object of the present invention is to provide a novel fiber having low coefficient of friction characteristics. It is a further object of the present invention to provide a fiber wherein the low coefficient of friction characteristics are permanent. It is yet another object of the present invention to provide articles possessing low coefficients of friction including apparel, bandages, bedding, footwear and accessories.

In accordance with the present invention, a low friction fiber is provided comprising a polymeric component and a low friction component, wherein the polymeric component is combined with the low friction component, thereby imparting onto the fiber a low coefficient of friction characteristic which is of a non-temporary nature.

Further, and in accordance with the present invention, methods and/or processes of forming a low friction fiber is provided including precompounding; utilizing low friction

particles; coating; and extrusion.

Still further, and in accordance with the present invention, there is provided a method of reducing the coefficient of friction in an article which comprises incorporating a low friction fiber comprising a polymeric component and a low friction component, wherein the polymeric component is combined with the low friction component, thereby imparting onto the fiber a low coefficient of friction characteristic which is of a non-temporary nature, into an article

It is apparent that the fibers of the present invention, and the articles made therefrom, have the advantages of, for example, low coefficients of friction, shock absorption, thermal stability, soil repellency, water repellency, oil repellency, acid repellency, low cost and ease of manufacturing into articles. Another advantage of the fibers of the present invention, and the articles made therefrom, is the avoidance or minimization of the development of irritations, blisters and calluses.

In this disclosure, "comprises", "comprising", and the like can have the meaning ascribed to them in U.S. Patent Law and can mean "includes", "including", and the like. These and other objects and embodiments of the invention are provided in, or are obvious from, the following detailed description.

DETAILED DESCRIPTION

The present invention provides a low-friction fiber, its methods and process for making it, and articles made therefrom. The fiber is comprised of at least one polymeric component and at least one low friction component, wherein the low friction component, when combined with the polymeric component, imparts a low coefficient of friction characteristic onto the fiber. The present invention also provides for a method of reducing the coefficient of friction of a fiber comprising the steps of combining a polymeric component and a low friction component; and forming a fiber from the combination of the polymeric component and the low friction component. It will be understood that the low coefficient characteristic is of a non-temporary nature, such as a permanent or lasting nature. An example of a low friction component is ultra high molecular weight silicone, which is environmentally friendly and degrades into sand.

The fiber of the present invention achieves a low coefficient of friction through

the use of at least one polymeric component and at least one low friction component. Such a polymeric component may include, but is not limited to, polyester, nylon, acrylics, aramids, polyethylene, polyurethane and plastic copolymers. The concentration of the polymeric component typically comprises 30% by weight of the total fiber; preferably from about 70-97% by weight of the total fiber most preferably from about 80-95% by weight of the total fiber. Suppliers of the polymeric component include, for example, DuPont, Nilestar, Wellman and Foss. One of ordinary skill in the art would understand in light of the present disclosure that more than one polymeric component may be used, such as, for example, a blend of two, three or four different polymeric components may be used.

Examples of the low friction component includes, but is not limited to, fluorocarbon polymers (e.g., polytetrafluoroethylene (PTFE), polymers of chlorotrifluoroethylene, fluorinated ethylenepropylene polymers, polyvinylidene fluoride, hexafluoropropylene, etc.) boron, molybdenum sulfide, ultrahigh molecular weight silicone, siloxane, fluoroesters (e.g., FLUOROPLENE[®]), fluorinated ethylene propylene copolymers (FEP), perfluoroelastomers (e.g., Viton[™], etc.), polychloro, trifluoroethylene homo- and copolymers (e.g., Aclar[™], etc.), silicone/silane modified polymers, graphite, fluorinated high molecular weight polyolefins or cyclic organic compounds, non-modified polyolefins, or other fluoropolymers (e.g., HALAR[™]).

The concentration of the low friction component typically comprises about 70% by weight of the total fiber; preferably from about 5.0 to about 30% by weight of the total fiber; most preferably from about 3.0 to about 20% by weight of the total fiber, even more preferably from about 0.2 to about 1.0% by weight. Suppliers of the low friction component include, for example, DuPont, Dow Corning, Ausimont and General Electric.

The low friction component may exist in the form of, but not limited to pelletized spheroidal beads, fibers or powders. A preferred low friction component includes ultrahigh molecular weight silicone, such as SILOXINE[®] manufactured by Dow Chemical. Other preferred low friction components include FLUOROPLENE[®] manufactured by Peach State Labs, and FIBERFILL[®] manufactured by DuPont as a TEFLON[®]-coated staple product.

The preferred low friction component FLUOROPLENE[®] is a fluorocarbon ester and may be compounded or master batched into, *inter alia*, chip additives or directly fed via injection ports on an extruder. One advantage of using FLUOROPLENE[®] is that it adds hydrophobic and oleophobic properties to extruded polymers. Another advantage is that

FLUOROPLENE[®] has a thermal decomposition temperature range of from about 220°C to 280°C. A still further advantage of using FLUOROPLENE[®] is that it is biodegradable.

One of ordinary skill in the art would understand that more than one low friction component may be used, such as, for example, a blend of two, three or four different low friction materials. It is to be understood that the present invention has a broad spectrum of utility, for example, the present invention can be used for, but not limited to, apparel, apparel accessories, bedding, bandages, bed sheets, footwear, footwear accessories, hospital gear, domestics, mattresses and upholstery.

It is further envisioned that other materials may be blended with other components such as, for example, flame retardants, antimicrobials, and anti-static agent that impart improved physical properties such as, for example, high-temperature resistance, increased melt temperature, increased workability, efficient thermal characteristics, and deformation-resistance.

The fibers of the present invention, which are made from one or more low coefficient of friction materials, are more cost effective than standard low coefficient of friction filaments and staple. This is because only a percentage of the invention's fibers contain low coefficient of friction material, while many of the standard low coefficient of friction filaments, such as TEFLON[™], and staple completely comprise low coefficient of friction materials. Since low coefficient of friction material is a premium product and the fibers of the invention contain less such material than the standard low coefficient of friction filaments and staple, the fibers of the invention are relatively cheaper than the standard low coefficient of friction filaments and staple.

There are several methods by which the polymeric and low friction components can be combined. One such method involves precompounding the polymeric component with the low friction material wherein the precompounded polymeric component melts and becomes bonded with the low friction material. Another such method involves utilizing low friction particles such as TEFLON[®] beads that are blended with the polymeric component. A further method is coating the low friction component permanently onto the surface of the polymeric component. A still further method includes extrusion whereby the low friction component is extruded into the polymeric component. Another method includes spray coating or mechanical dipping. Still another method includes sheath and core.

Once the polymeric and low friction components are combined, the fiber in

accordance with the present invention may be made according to several known methods. Such methods include, for example, extrusion; sheath and core; and slicing fibers that are formed in a thin film. The fibers may be formed into mono- or multifibers or into staple fibers, with a denier of from about 0.5 to about 1500. Further, once the fibers are formed, they may be made into articles by spinning, weaving, stitch non-weaving, spun-bond and/or melt-blown. The fibers are imparted with a coefficient of friction of about 0.22 to about 0.005; preferably from about 0.15 to about 0.01; most preferably from about 0.01 to about 0.005.

EXAMPLES

The following examples are set forth to illustrate examples of embodiments in accordance with the invention, it is by no way limiting nor do these examples impose a limitation on the present invention.

EXAMPLE 1: Methods of Combining Polymeric and Low Friction Components

A) Blending:

Blending normally refers to the ambient temperature mixing of all or some of the ingredients of the pre-compounded or post-compounded formulation ingredients. Blending usually, but not always, involves materials of similar physical size. In special cases, blending refers to the intensive paddle mixing of powders and sprayed liquids.

In the manufacture of articles using the present invention, either or both of pre-compounding blending or post-compounding blending may be used. Pre-compounding blending is the process used to mix some or all of the formulation components prior to melt compounding and is typically conducted at ambient or reduced temperatures. The need and/or desirability for pre-compounding blending depends upon a number factors. Among these are:

- a) The specific type of melt compounding or extrusion equipment to be used in the process;
- b) The capability of the feed equipment, for the melt processing of the formulation, to handle liquids, powders, pellets, and other types of physical forms;

- c) Specific appearance and/or performance attributes desired in the finished fiber;
- d) The relative economic impact on production of pre-compounding blending, in-line compounding/extrusion and post-compounding blending.

Post-compounding blending is the process of non-melt mixing of the compounded, pelletized or granulated formulation. This type of blending is often used to combine two or more compounded batches of material to achieve a larger finished batch having more uniform properties. Post-compounding blending may also be used to add one or more additives to the pelletized material prior to extrusion. For example, a non-pigmented batch of the low friction formulation may be compounded and extruded. After pelletization, the non-pigmented pellets may be post-compounded blended with appropriate pelletized additives (color, UV absorber, antioxidant, flame retardant, plasticizer or impact modifier, etc.). This technique results in a uniform, pelletized batch of material ready for extrusion. It is often used when the additives have questionable thermal stability or specific visual, or performance attributes are required in the fiber.

Equipment typically used in pre-compounding blending includes, but is not limited to:

1. Henshel, ribbon and other similar mixers, designed for the blending of powders;
2. Barrel, drum, barrel or cement and similar types of mixers designed for mixing pellets;
3. Specialized mixers designed to coat powders and/or pellets with liquids;
4. Ball Mills and similar types of mixers designed to grind and mix either simultaneously or sequentially.
5. Littleford mixers and similar designed paddle mixers designed for blending powders, granules, pellets and friable particulates.

Equipment typically used in post-compounding blending includes, but is not limited to:

1. Any of those used for pre-compounding blending;

2. Silo and other similar blenders designed for homogenizing large volumes of compacted or densified particulates;
3. Fluidized bed and other similar mixers designed to use high velocity gaseous streams to homogenize materials and/or remove or segregate materials having different bulk densities.

B. Compounding

Compounding is the melt mixing or homogenization of one or more of the major components of the fiber component materials. The compounding equipment may consist of any one or more of the following:

- i. Single or twin screw extruders, in which the appropriate ingredients are added to the rear end of the extruder. The combination of:
 - a. Heat, from the barrel and/or extruder screw(s),
 - b. Shear heat, due to mixing of the ingredients,
 - c. Frictional/compressive heat, generated by rubbing of the materials against the interior extruder barrel and compression between the barrel wall and extruder screw,cause a reduction of viscosity of the total mass. In some cases, additional materials may be added at other locations along the barrel between the initial entry port of the raw materials and the exit die.
- ii. Continuous mixers, in which one or more screws, or screw elements, continuously transport, compress and shear the materials to reduce their viscosity and improve the homogeneity of the mass. Continuous mixers may also contain disks or taper rotors and/or barrels. The continuous mixer may exit the molten mass through a die or other discharge port.
- iii. Batch mixers, in which the ingredients are added to a chamber that contains blades, paddles or rotors. The chamber is then closed and the revolving devices within it begin to rotate. The combination of shear heat generated by these devices and external heat supplied from the heated walls of the mixer, reduce the viscosity and increase homogenization of the contained materials. When the compounding is complete, the chamber

opens in a manner to allow its fluxed contents to drop onto, or into another device to define the size and shape of the molten mass. The mass may be shaped into pellets, slabs, rods or other convenient shapes by this secondary device.

C) Coating:

Practice of the present invention may include coating of one or more of the starting raw materials, as described above, and/or coating of the pre-spun extrudate and/or coating of the finished fiber. The coating processes may include:

- i. Coextrusion, in which the coating is extruded on one or more sides of the base fiber, or in a manner to completely surround the outer surface of the base fiber. Coextrusion also includes the extrusion of the fiber through a die immediately followed by intimate contact with the coating material as the coating liquid emerges from another portion of the same die or another die adjacent to, or surrounding the primary fiber die.
- ii. Physical dipping, where the base fiber is dipped into, or pulled through a container which contains a liquid form of the coating. The liquid form of the coating includes coating solutions, emulsions, dispersions, gels or suspensions.
- iii. Spraying, where the coating, either particulate or liquid, impinges upon the fiber surface in an environment designed to cause adhesion to, entanglement with, or encapsulation of the base fiber.
- iv. Plasma or vapor deposition, where the fiber passes through an environment in which an electric discharge, and/or radiation cause the coating molecules or atoms, also in the environment, to adhere and/or chemically bond to the base fiber. The bonding process may be accompanied by chemical reaction among the coating molecules or atoms.

- v. Surface molecular polymerization, a process in which one or more types of reactive molecules and/or atoms are introduced into a chamber containing the fibers. Such reactive species polymerize and/or chemically react with the fiber surface. External energy sources may or may not be required. An example of surface molecular polymerization in the present invention is the introduction of parylene into a chamber containing polyester and/or other fibers. The resulting parylene coated fibers have a lower COF and are more chemically inert than their non-coated precursors.

It is understood that in any of the above examples, catalysts and/or co-reactants may also be used. The present invention also includes the coating of the finished fiber after its inclusion into a woven or non-woven fabric.

D. Extrusion

In extrusion, either a:

- i. Pre-compounded blend,
- ii. Compounded blend, or
- iii. Post-compounded blend,

as described above, of the base polymeric component(s) and the low friction component(s), where said low friction component(s) may also consist of a:

- iv. Pre-compounded blend,
- v. Compounded blend, or
- vi. Post-compounded blend,

are melted, or subjected to a sufficient reduction in their viscosities, such that they can be pushed or pumped through the extruder cylinder or chamber and through one or more dies. The die(s) may have one or more nozzles and may be stationary or rotating. The extruder may have a single screw, two or more screws or one or more rotating or stationary disks to facilitate the viscosity reduction of the polymeric materials, melting or softening of any additional materials in the feed stream and pumping the mass to the die(s). In addition to typical extruders, devices known as continuous mixers may also be used in this operation. Typically, the extrudate will consist of

fibers in which the low friction component congregates on the exterior fiber surface and the base polymer occupies the interior of the fiber. In cases where the fiber is coextruded, the base fiber component exits from the extruder die and is immediately encapsulated by, or adhered to, the low friction component, which emerges from another die, concentric or adjacent to, the base fiber die.

Typically, fibers have diameters from less than 0.004 mm (0.00015") to 0.2 mm (0.008"). Fibers may be produced in many forms: continuous single fibers (monofiber), short fibers (staple or chopped), untwisted bundles of continuous fibers (tow), twisted bundles of continuous fibers (yarn), etc.

EXAMPLE 2: Methods of Forming Fiber

A. Spinning:

Spinning is the process by which a molten, viscous mass is extruded, drawn or pulled to form a fiber. The drawing may include twisting the fiber into yarn or thread. There are three forms of spinning commonly used, and a fourth specialty process occasionally used for specialty fiber production:

1. Melt Spinning in which the polymer is melted and pumped through a spinneret with numerous holes (one to thousands). The molten fibers are cooled, solidified, and collected on a take-up wheel. Stretching of the fibers in both the molten and solid states provides for machine direction orientation of the polymer chains along the fiber axis. Polymers such as PET, polyamides (nylon), polyolefins, and polyvinylidene chloride are produced this way. Melt spun fibers are readily amenable to the low friction fiber production and are the preferred materials, considering cost/performance attributes.
2. Wet Spinning is used for fiber forming materials that have been dissolved in a solvent or suspended in an emulsion. The dissolved polymer is extruded and pumped through spinnerets whose exit points are below the surface of a liquid chemical. As the extruded fibers emerge from the spinneret, the liquid chemicals cause the dissolved fiber to precipitate out of solution and form solid fibers. Wet spun low friction fibers can also be produced. In practice of the present invention, it is preferable to coat the wet spun fiber after

fibrillation, rather than to simultaneously wet spin a liquid dispersion or emulsion of the base fiber polymer and the low friction component.

3. Dry spinning is also used to form polymeric fibers from solution. The polymer is dissolved in a volatile solvent and the solution is pumped through a spinneret. As the fibers exit the spinneret, air is used to evaporate the solvent. The fibers solidify and can be collected on a take-up wheel. Stretching the fibers provides for machine direction orientation of the polymer chains along the fiber axis. In practicing the present invention, dry spun fibers are preferably coated with the low friction component rather than dry spinning a dispersion or emulsion of the base fiber polymer and low friction component.
4. Gel Spinning, specialty process, is used to produce high strength and other specialty fibers. The base polymer is in a gel state, not in solution during extrusion. The high polymer concentration per unit volume of gel results in high polymer entanglement during extrusion. The resulting fibers have very high tensile strength in the machine direction due to shear alignment and orientation. In the practice of the present invention, gel spun fibers are preferably coated with the low friction component after fibrillation, rather than gel spinning a viscous gel blend of the base fiber polymer and low friction component.

An example of the manufacture of the low coefficient of friction fiber of the present invention is given below:

The low COF component may consist of an ultra-high molecular weight polysiloxane. This material may be pre-compounded, using one or more of the types of compounding equipment described above, or similar compounding devices, with the base fiber polymer and/or a polymeric binder which is compatible with the base fiber material. The pre-compounded blend is pelletized or shaped into some other physical form, that will be readily handled in other equipment to be used in the process. It is understood that other low COF materials may be used in place of, or in addition to, polysiloxane. Such other low COF materials may include, but are not limited to, FLUOROPLENETM, fluorinated ethylene propylene copolymers (FEP), particulate polytetrafluoroethylene (PTFE), perfluoroelastomers (ex. Viton,

etc.), polychloro, trifluoroethylene homo- and copolymers (ex Aclar, etc.).

The pelletized, low COF blend and pellets of the base polymer are introduced into an extruder, as described above. Additional materials, such as pigment masterbatches, UV absorber and/or antioxidant master batches, monomeric and/or polymeric plasticizers or impact modifiers may also be added to the extruder.

The extruder die consists of one or more spinnerets. A spinneret is a die with one or more (1000+) small holes. Melt spinning is the preferred method of manufacture for polymeric fibers. The molten polymer is pumped through the spinneret. The molten fibers are cooled, solidified, and collected on a take-up wheel.

Stretching of the fibers in both the molten and solid states provides for machine direction orientation of the polymer chains along the fiber axis. Polymers such as polyethylene terephthalate (PET), polypropylene (PP) and nylon (PA) 6,6 are examples of melt spun fibers.

B. Fiber Geometry and Construction

For each of the spinning techniques, described above, a variety of fiber shapes may be produced. Finished fiber shape may be determined by: 1) shape of the spinneret holes through which the fiber passes; 2) composition of the fiber material; 3) shrinkage of the fiber components affects finished fiber shape; 4) inclusion of blowing agents in the composition may also affect finished fiber shape; 5) spinning technique employed.

Among the above spinning techniques, melt spinning allows the greatest control of fiber geometry and shape. Wet, dry and gel spinning, offer less precise control of finished fiber shape due to the presence of solvents that must be removed during and after the spinning process.

Low COF fibers may be produced using each of the above spinning processes. Bipolar, triangular, oval, rectangular and several other shapes may be produced. For gel, wet and dry spinning, coating of the finished fiber by the low friction component(s) is preferred. Such coatings may be applied to any of the possible fiber shapes. Depending upon finished fiber geometry, such coated fibers may have lower or higher coefficients of friction (COF) than typical circular fibers. Shaped low friction fibers allow the possibility of less surface area contact between the low friction surface and external surfaces. Rectangular shaped low friction fibers may have higher COF's than circular ones due to greater surface area contact with external surfaces.

The effective COF of low friction fibers is also affected by the modulus or stiffness of the base fiber. Stiffer or higher modulus base fibers usually have lower COF's than softer or low modulus base fibers. This is due to the greater compressibility of lower modulus fibers. Such compression of the fiber surface increases the area of contact between the low friction surface and external surfaces.

Low friction fibers of the present invention may have a sheath/core construction in which the sheath is usually the low friction component and the core is the base polymeric component. The economic advantage of this type of construction is that the low friction component is often the more costly component. As the sheath, surrounding the core, a thin layer of the low friction component is required to perform its intended function. Additionally, the sheath, located on the outside of the core, presents a low COF surface to the outside world. Gauge of the low friction sheath layer may be increased, if required, to further enhance specific fiber properties and/or performance attributes. It should be noted that, if required, the low friction component may be produced as the core, with the higher friction component as the sheath. This type of structure is useful for those applications that require an initial high COF surface that is abraded over time to yield a low COF fiber surface.

A skilled artisan would readily understand that with any fiber geometry, the low friction component may be affixed to only a portion of the base fiber surface. Both coating and coextrusion processes are capable of achieving such constructions. Constructions having the low friction component on only a portion of the fiber surface offer advantages in selected types of fiber applications:

a) **Side-by-Side Structures:** Shrinkage of the low friction component is usually less than that of the base fiber, due to the greater crystallinity achieved by the base fiber during spinning. Side-by-side fibers of this type will have a natural tendency to curl, resulting in an increase in their bulk volume. This increase in volume, with no change in weight, results in a fiber having enhanced softness. The curled fibers have a greater tendency to entangle resulting in increased resistance to fiber separation in woven and non-woven fabrics. Such curled fibers, having a large volume compared to their weight, may also be useful in thermal and acoustical insulation applications.

b) **Spun Bonded Structures:** With the low friction component on only a portion of the base fiber surface, fabrics which are spun bonded, yield improved softness ("hand") and

increased resistance to fiber separation. These are due to the increase in structure volume, as described above, and enhanced bonding between fibers due to the ability of the base fiber polymer to melt bond to bond to itself. This ability is generally increased since the low friction component usually contains fluoropolymer or siloxane entities, which have high softening temperatures, and are amorphous, having no sharply defined melting point. During the spin bonding process, the low friction component generates less frictional heat and experiences less viscosity decrease than the base fiber polymer. This yields more interfiber bonding between the base fiber polymer segments with itself. The net result is a spun bonded structure having a lower bulk density, greater "softness" and stronger interfiber bonds.

C. Continuous & Staple Fibers

Continuous fibers are those consisting of long, unbroken lengths of fiber. Fiber produced using the technology of the present invention may be of the continuous fiber variety. Continuous fiber is often cut into shorter lengths called staple. Staple fibers are easier to work with than continuous fibers due to their shorter lengths. The present invention can be utilized in both continuous and staple forms. Typically, staple fiber is used in blends with other fibers. Their short lengths simplifies the fiber blending process. Blending of fibers is done to enhance the performance of the resulting garment. Low COF staple blend more readily than typical staple fibers due to their low COF surfaces. Such surfaces reduce surface-to-surface friction and permit the formation of homogeneous blends more rapidly than conventional fibers.

Fibers are often aligned and twisted together to form thread or yarn. Fibers of the present invention are usually easier to twist with other fibers due to their low COF surfaces. Thread and yarn made with fibers of the present invention are often easier to use than conventional thread and yarn. The low COF components of such threads and yarns often reduce the drag forces encountered in sewing. The thread having low COF components pulls through fabric more easily than threads that don't contain such low COF components. This is a major benefit to those who have difficulty sewing because of problems pulling the thread through the fabric. Knitting with yarn that contains low COF fibers is similarly improved.

EXAMPLE 3: Articles

A) In one embodiment, low friction socks or hosiery can be produced incorporating low friction fibers of the invention overall or in specific areas, for example, high contact areas such as in the heel area.

B) In another embodiment, apparel, such as clothing, gloves, shirts, and hospital gear, can have low friction fibers of the invention overall or in specific areas. Further, the low friction fiber may be incorporated in either a single layer or in multilayers.

C) The low friction fibers can also be used in bandages and wraps which support torn and sore muscles, ligaments and joints and as linings for casts. The low friction fibers can be incorporated overall or in specific areas. Further, the low friction fiber may be incorporated in a single layer or in multilayers.

D) The low friction fibers can be incorporated into footwear, footwear inserts, and accessories, that will help avoid blisters and callouses by reducing friction. The low friction fibers can be incorporated overall or in specific areas. Further, the low friction fiber may be incorporated in a single layer or in multilayers.

E) The low friction fibers can be incorporated into mattresses, upholstery, bedding, bedsheets, sheets, pillows, pillow cases, mattress pads, for domestic, medical or commercial use. The low friction fibers can be incorporated overall or in specific areas. Further, the low friction fiber may be incorporated in a single layer or in multilayers.

F) The low friction fibers can be incorporated into sporting apparel, sporting equipment and accessories. The low friction fibers can be incorporated overall or in specific areas. Further, the low friction fiber may be incorporated in a single layer or in multilayers.

It is also understood that the invention is not limited to the detailed description of the invention, which may be modified without departure from the accompany claims.